Design and Analysis of a Hyperspectral Microwave Receiver Subsystem

W. Blackwell, C. Galbraith, T. Hancock, R. Leslie, I. Osaretin, M. Shields, P. Racette (NASA GSFC), L. Hilliard (NASA GSFC)

IGARSS 2012

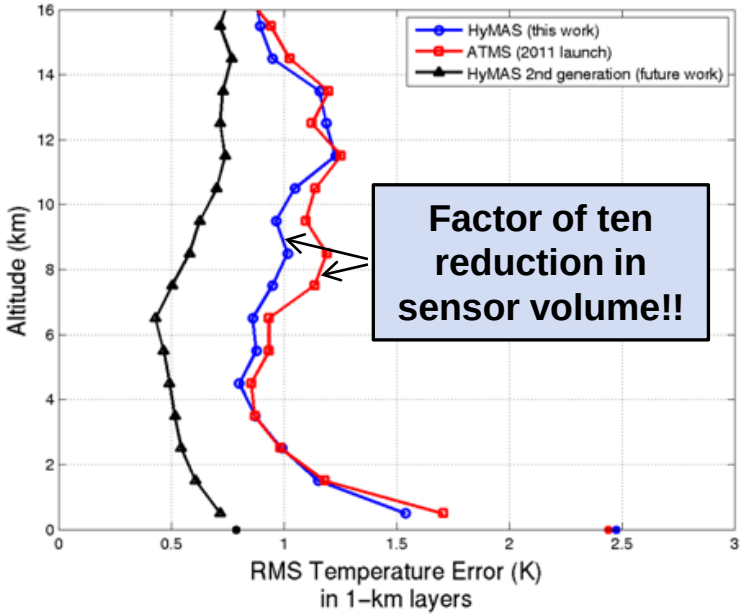
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

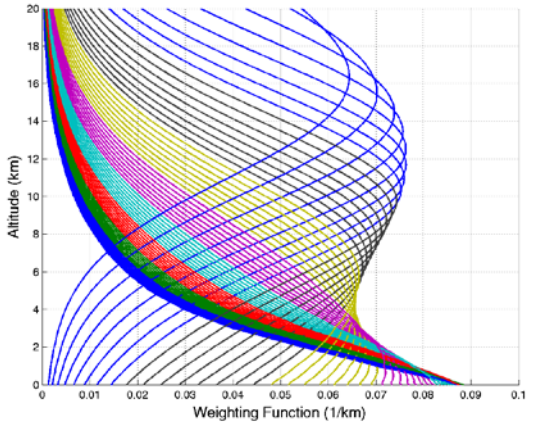
Outline

- **Project summary, key objectives, and roles/responsibilities**
- **RF receiver electronics and scan head**
- **IF processor module**
- **Next steps**

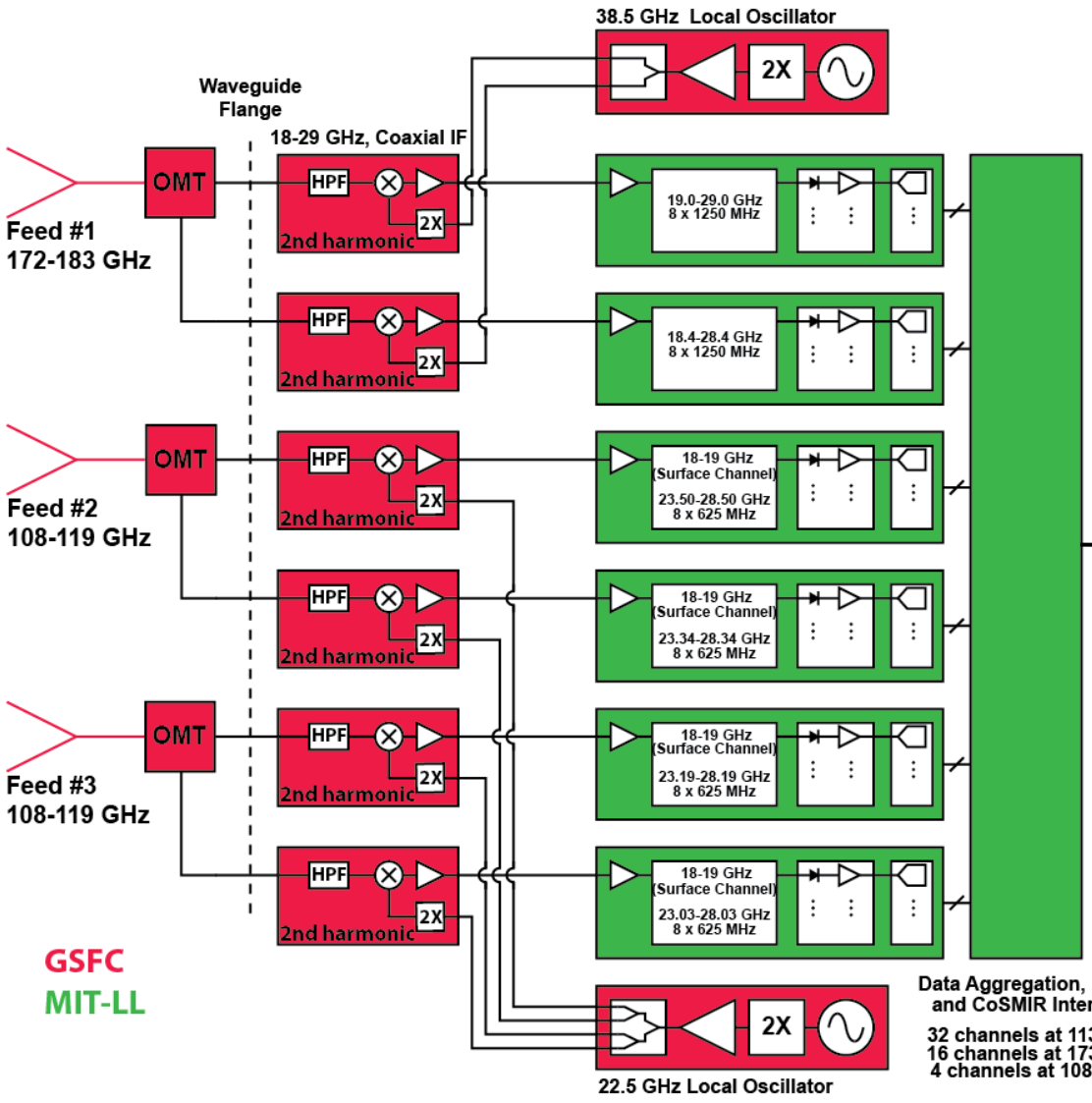
Project Summary and Key Objectives

- **Hyperspectral microwave (HM) sounding has been proposed to achieve unprecedented performance**
- **HM operation is achieved using multiple banks of RF spectrometers with large aggregate bandwidth**
- **A principal challenge is Size/Weight/Power scaling**
- **Objectives of this work:**
  - **Demonstrate ultra-compact (100 cm^3) 52-channel IF processor (enabler)**
  - **Demonstrate a hyperspectral microwave receiver subsystem**
  - **Deliver a flight-ready system to validate HM sounding**

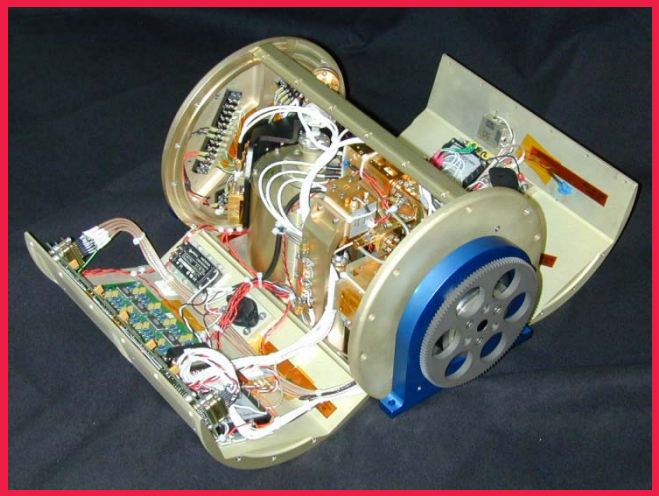




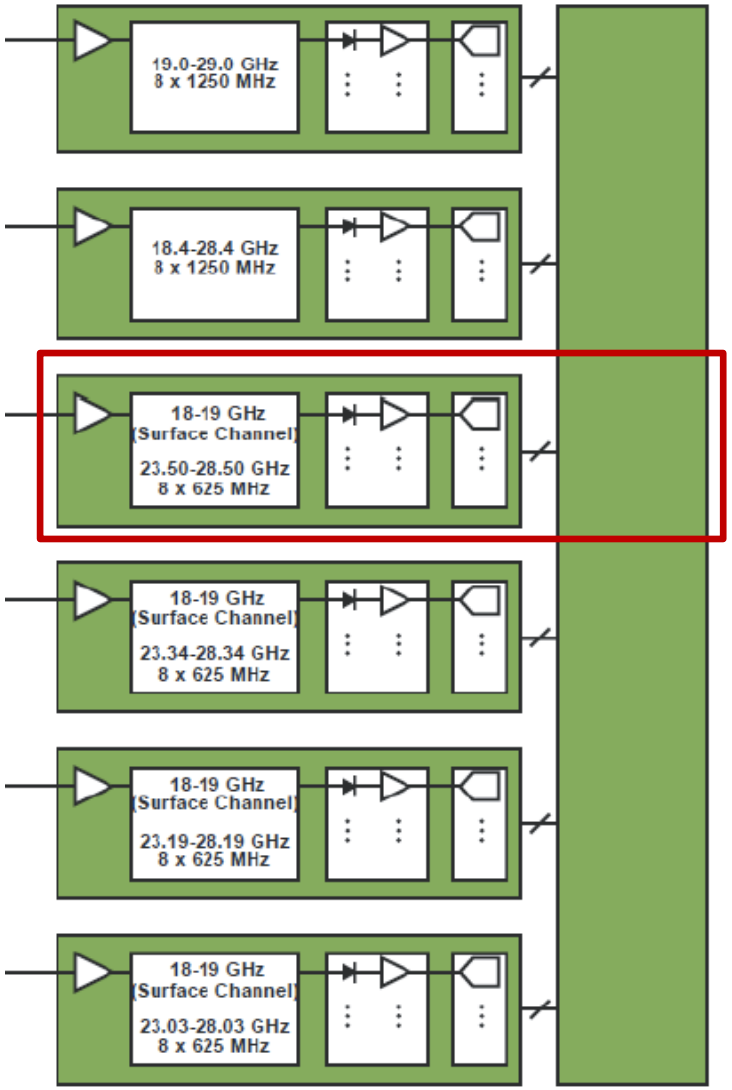
HyMAS System Components Roles and Responsibilities



Scan Head Assembly (GSFC CoSMIR/CoSSIR)



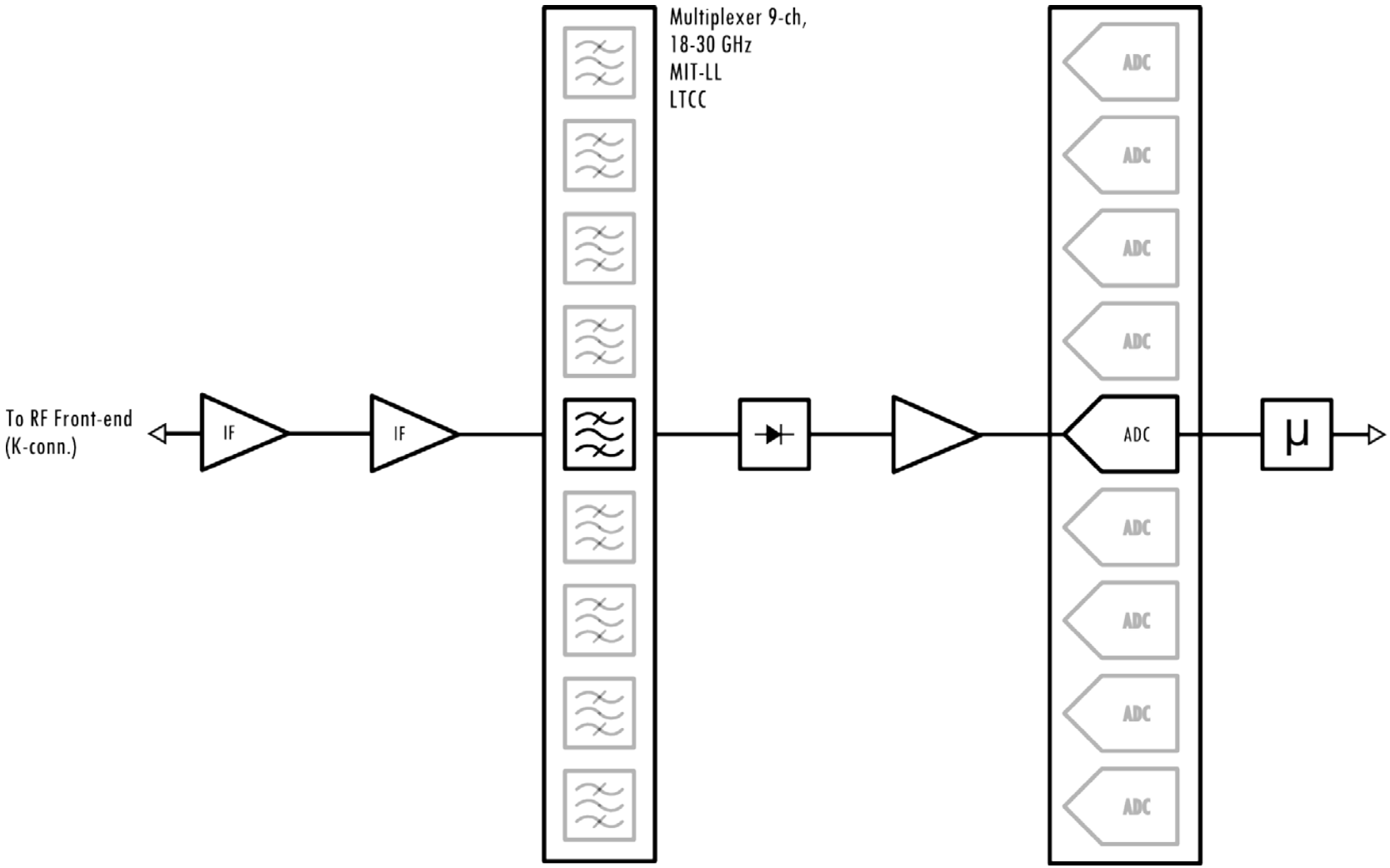
HyMAS (9-channel) IF Frequency Plan



IF Processor Description

- K-connector (18-29 GHz) input from RF front-end
- Two IF amplifiers (18-29 GHz)
  - Buffered with attenuators for gain adjustment and matching at IF input/output
    - Provides termination for RF front-end output and multiplexer input
    - Nominally 3 dB at input/output, “0 dB” in between stages
- Multiplexer channelizes IF band
- Detectors detect power at output of each channel
- Op-amp fed by detectors, drives ADC
- Microcontroller sequences data flow

HyMAS – IF Processor



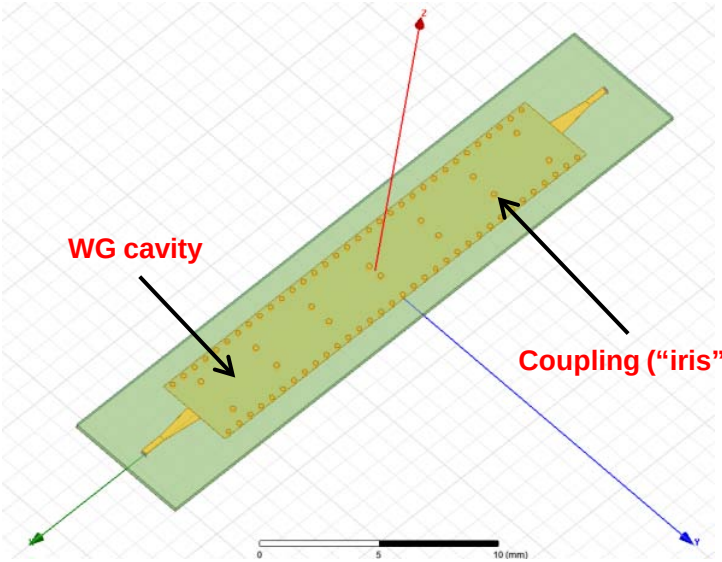
IF Multiplexer

- **Single port feeds 9-channels through a corporate feed power splitting network**
  - **Reduces interaction among contiguous channels**
  - **Low-risk for initial demonstration**
- **IF channel filters are LTCC-based substrate integrated waveguide (SIW) cavity types**
  - **High unloaded *Q* resonators (500+) in small volume for low insertion loss and sharp filter skirts**
  - **Probe/bond pads for S-parameter testing and assembly**
- **First 9-channel design completed and in fabrication**
  - **Omega Micro Technology (DuPont 9K7), expect parts in 9/2012**

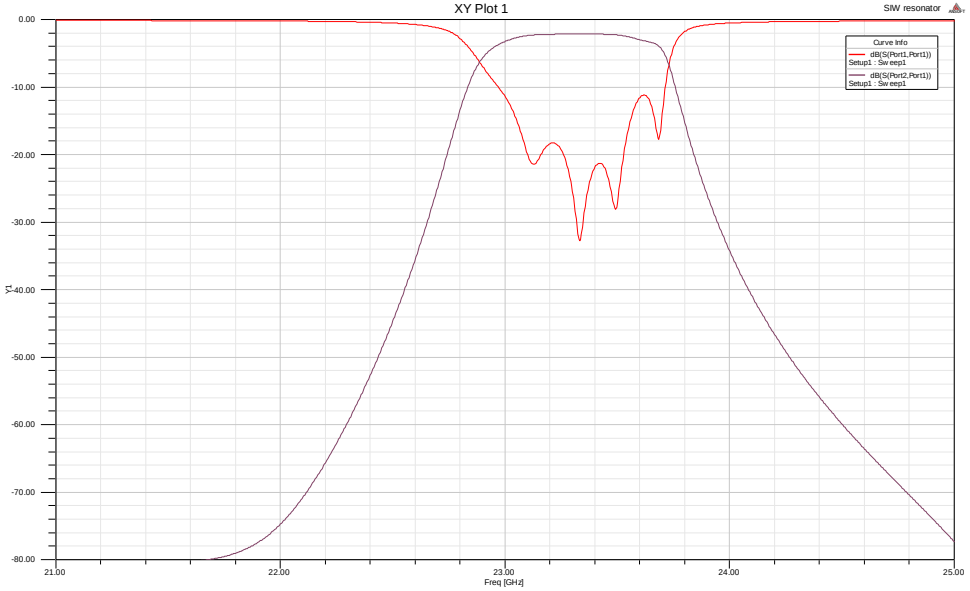
HyMAS LTCC SIW Filters

- **Substrate Integrated Waveguide (SIW) filters offer lower insertion loss and better filter shape factor than stripline interdigital filters due to their higher *Q* (> 500) resonators**
  - **Filters are realized in two-layer LTCC stack with via "fences" creating the waveguide side walls**
  - **Via "posts" control coupling in between resonator cavities**

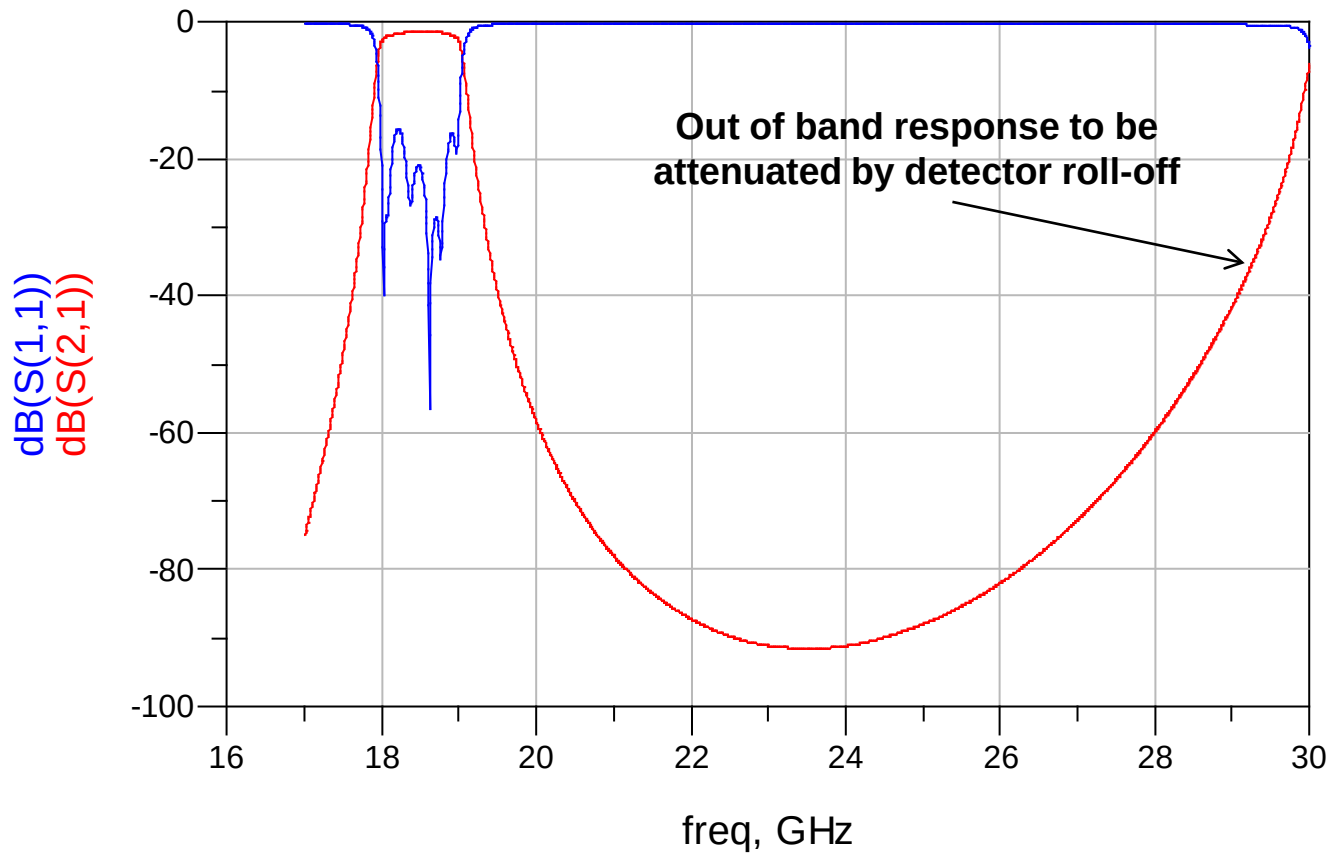
HFSS Model



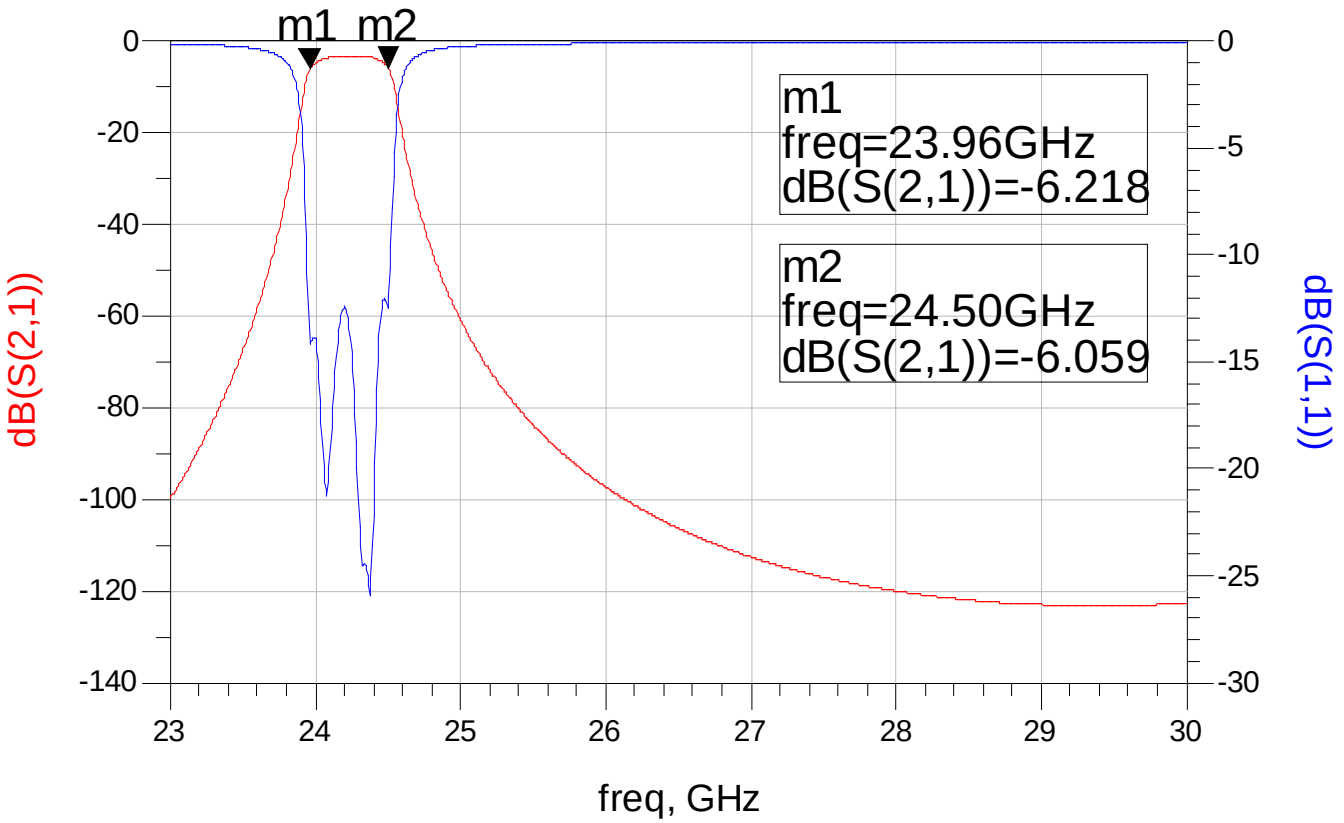
HFSS Simulation



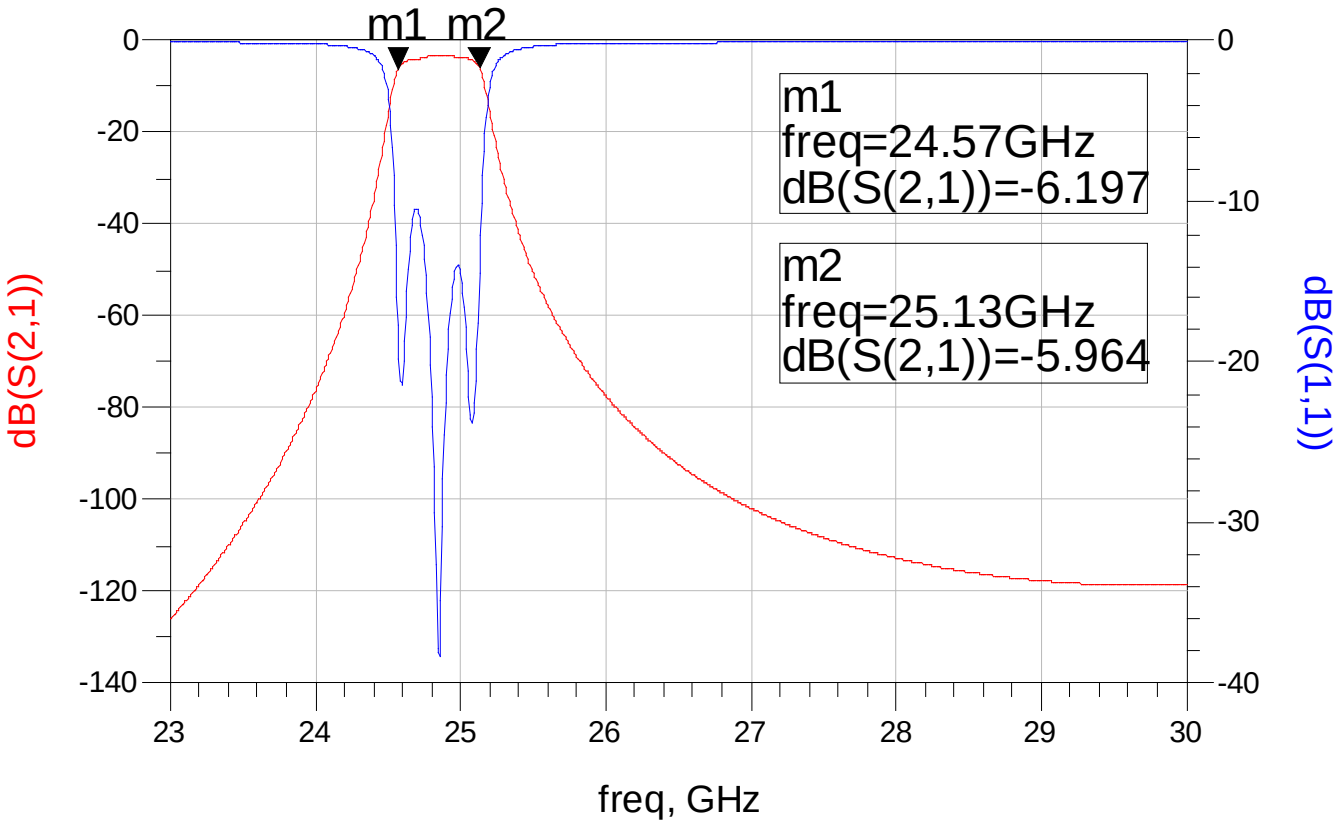
IF Channel 1 (HFSS)



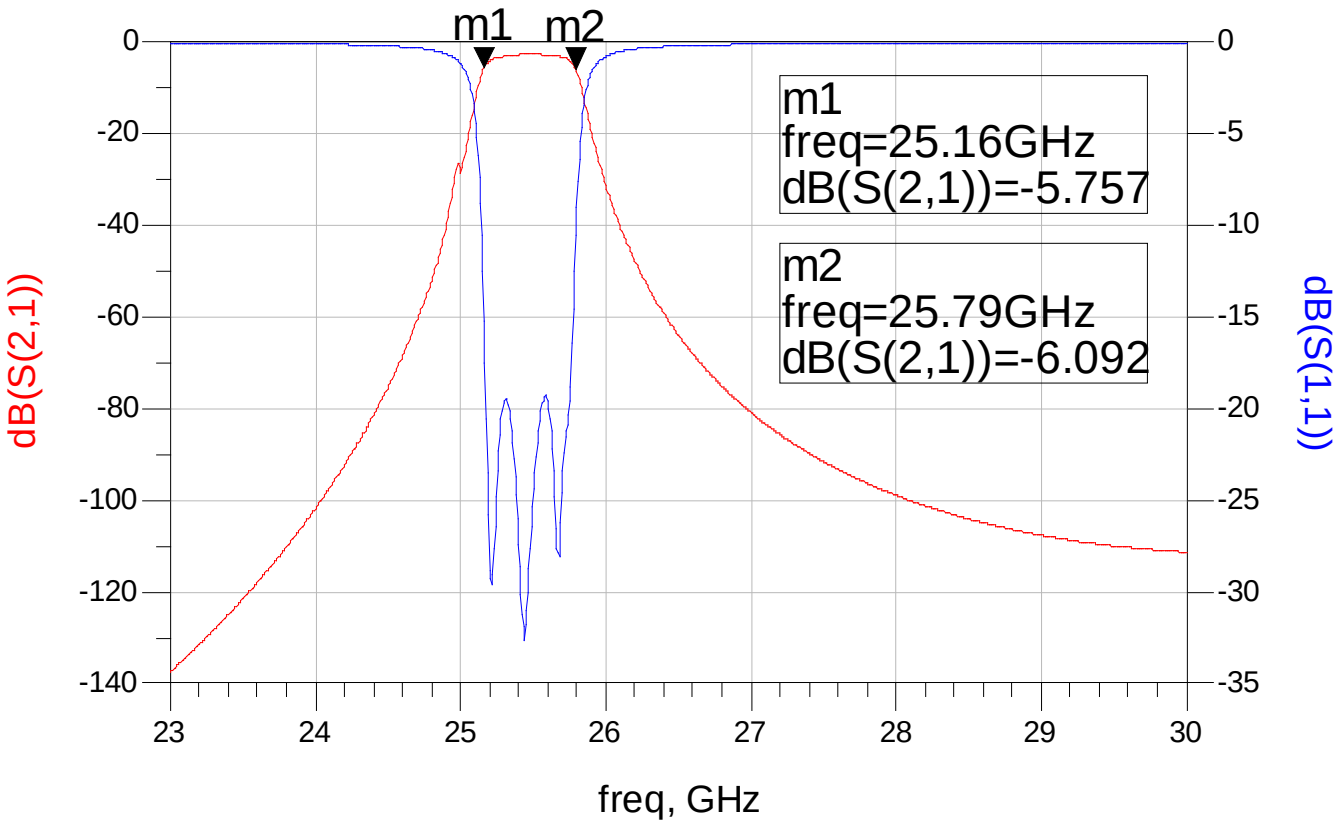
IF Channel 2 (HFSS)



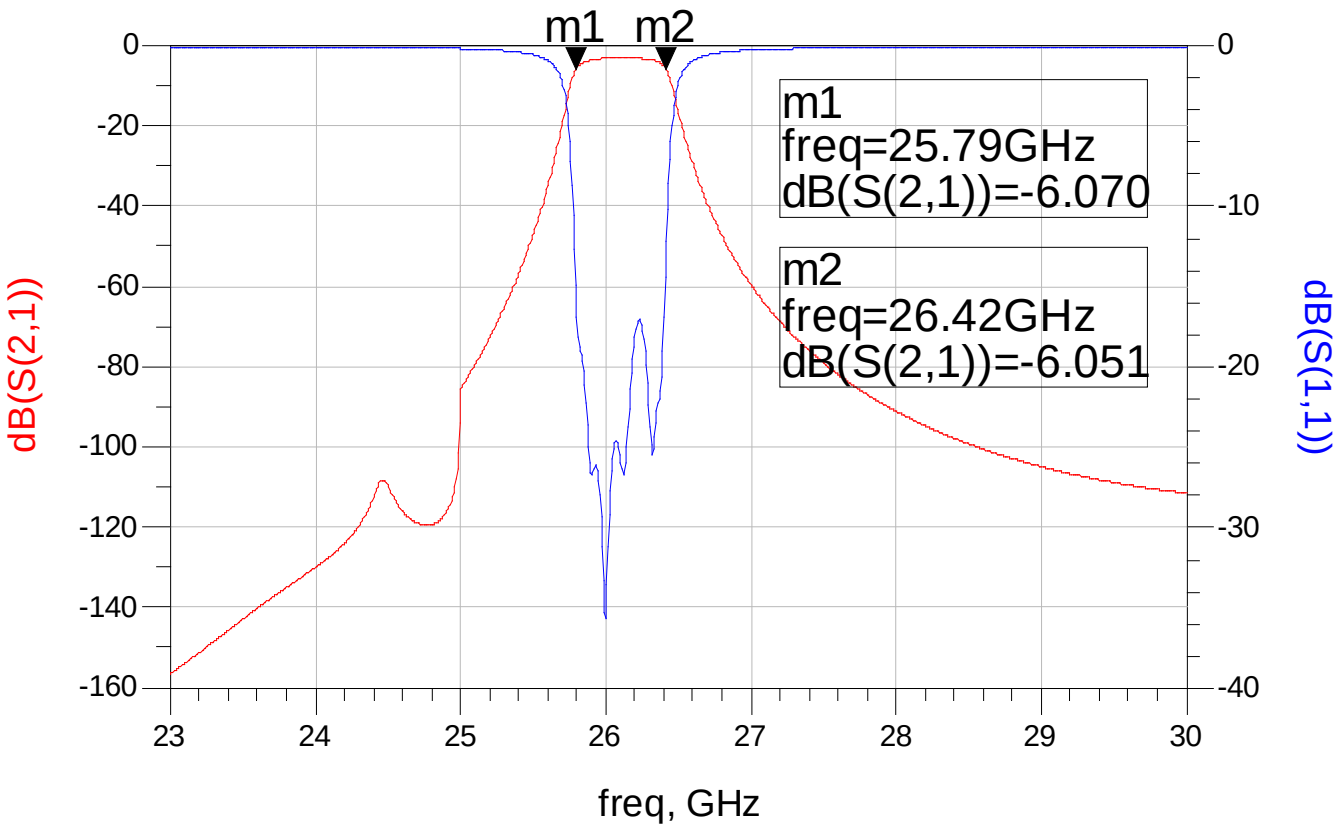
IF Channel 3 (HFSS)



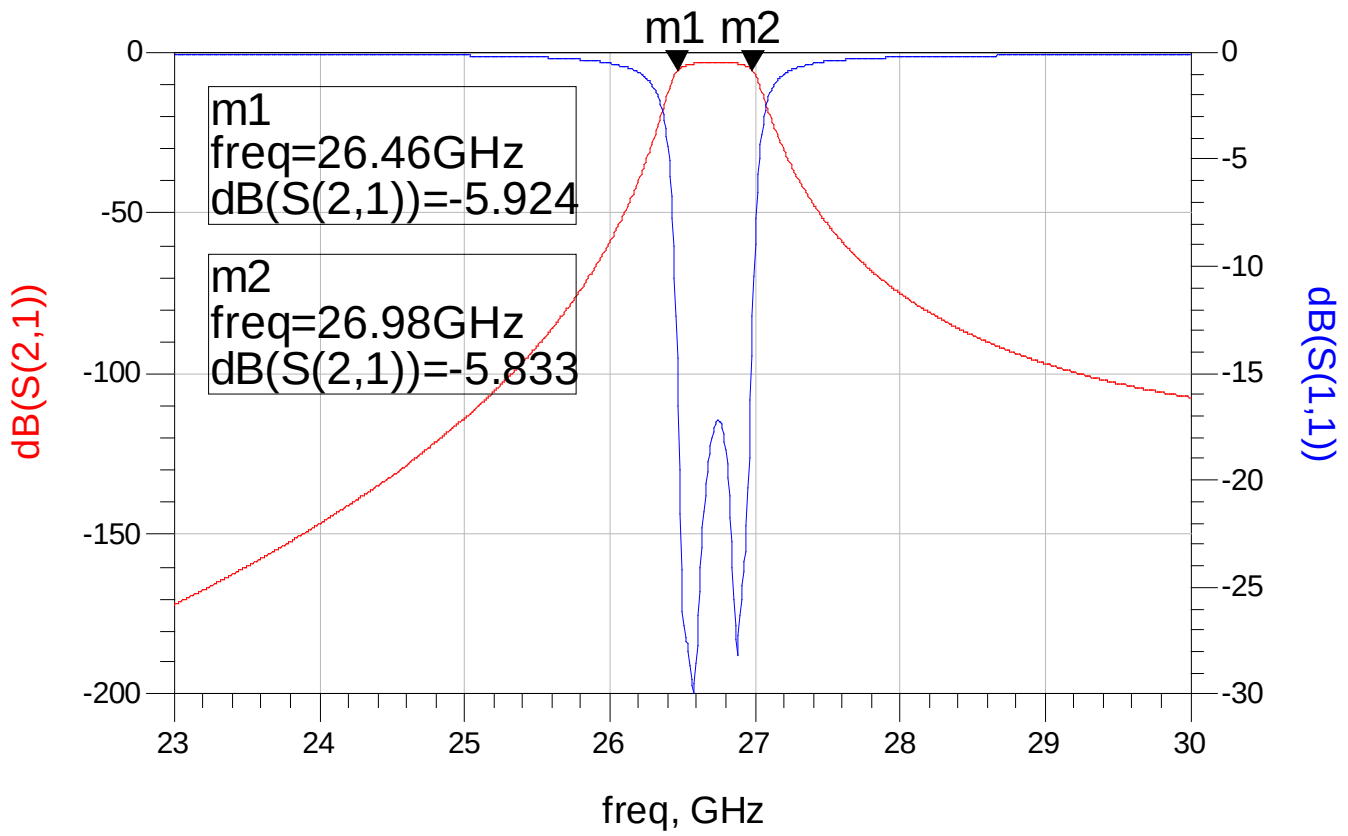
IF Channel 4 (HFSS)



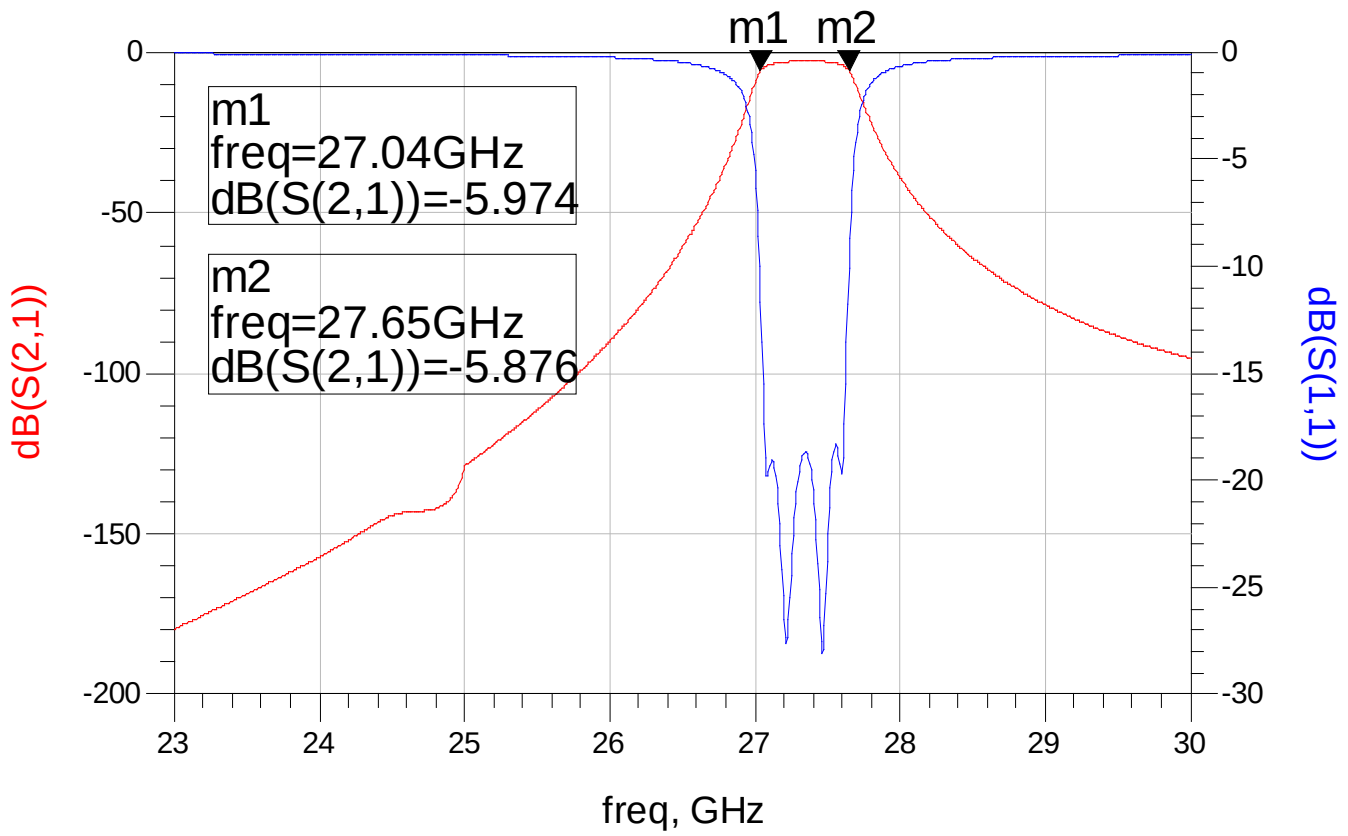
IF Channel 5 (HFSS)



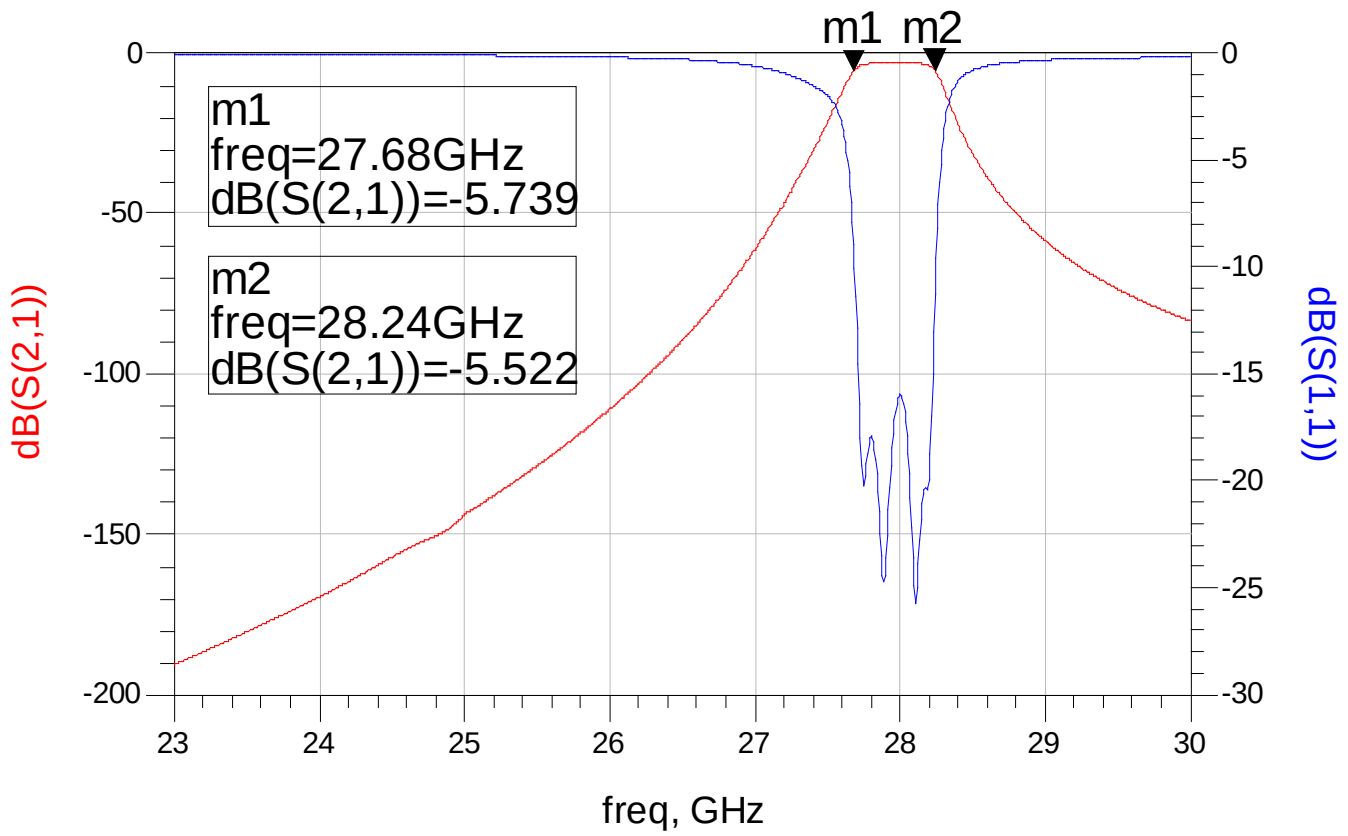
IF Channel 6 (HFSS)



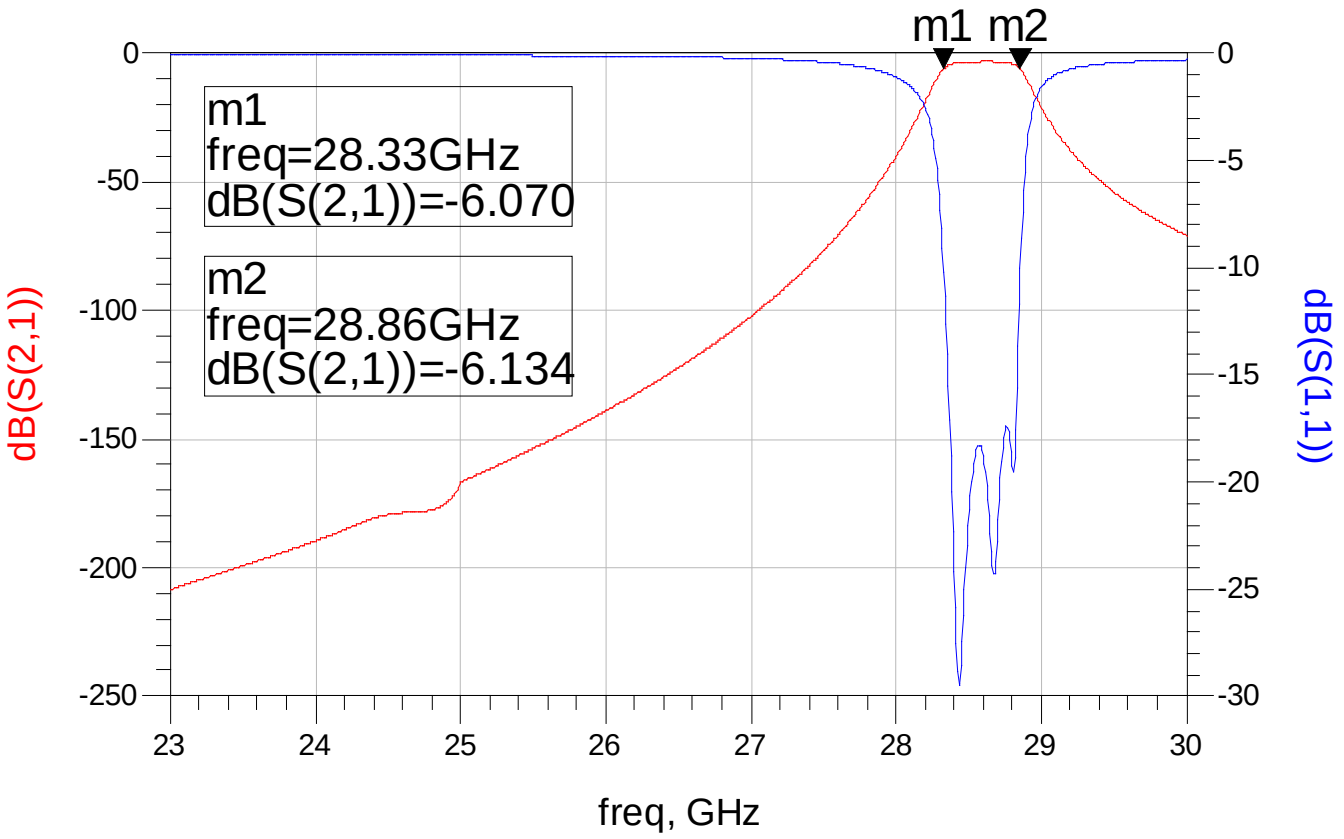
IF Channel 7 (HFSS)



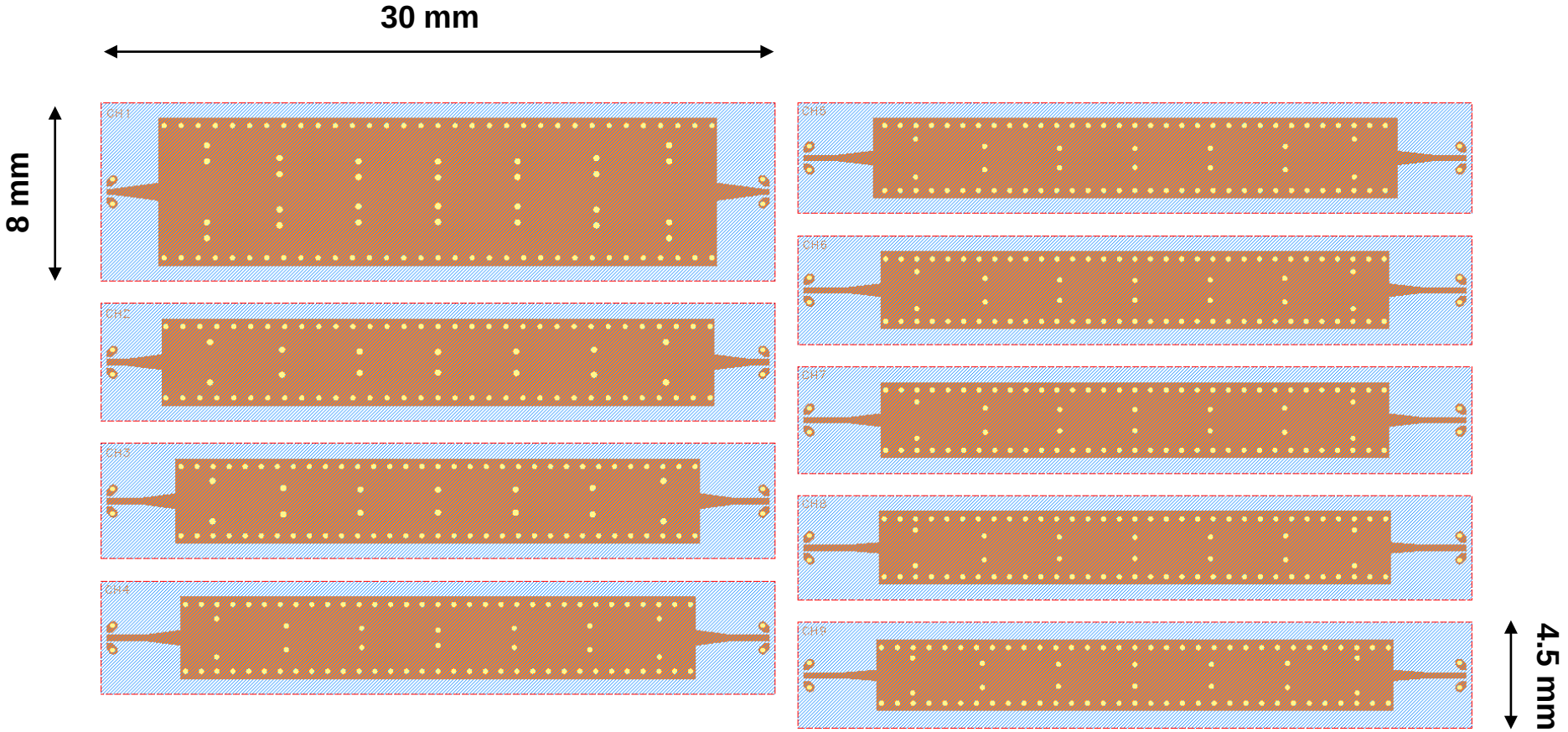
IF Channel 8 (HFSS)



IF Channel 9 (HFSS)

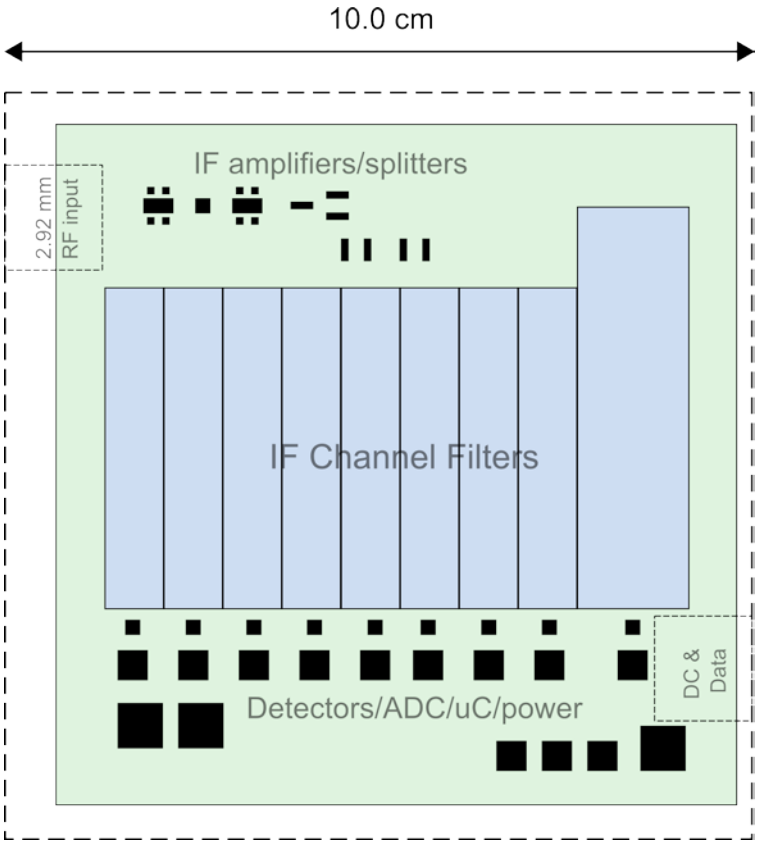


IF Filter Layout (LTCC)

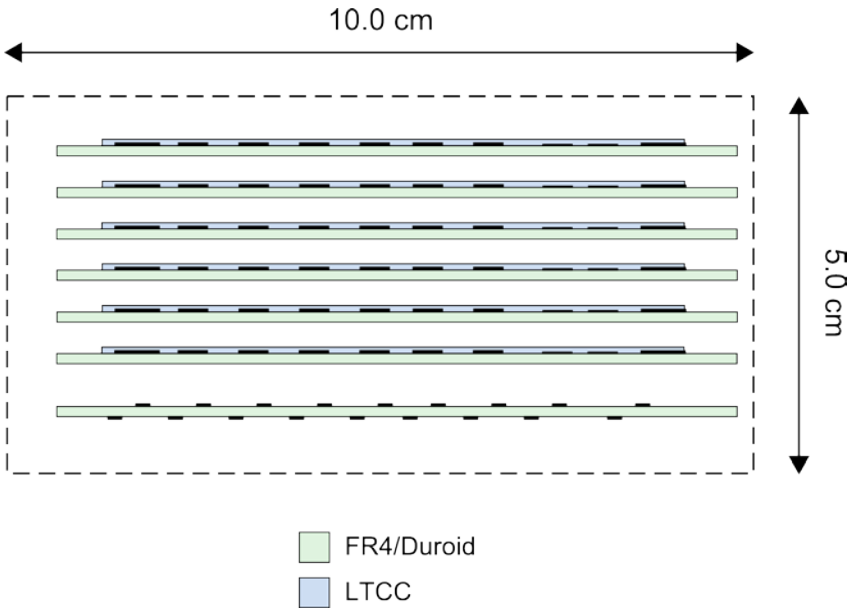


IF Processor Form Factor 1
Horizontal Resonators

Top View: 8/9-channel Panel

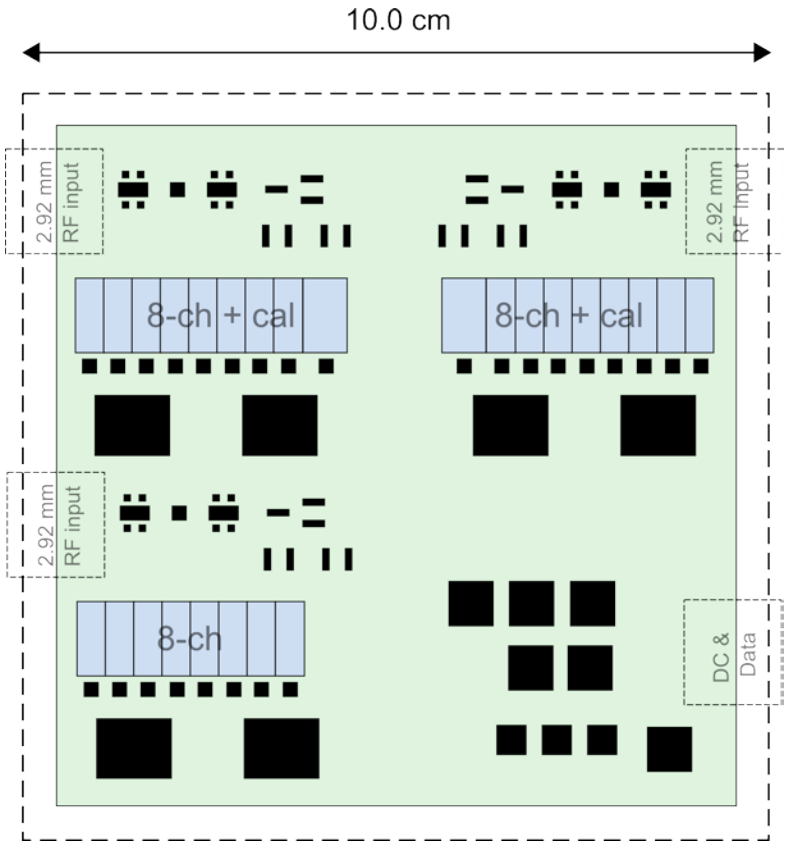


Side View: 52-ch IF Processor

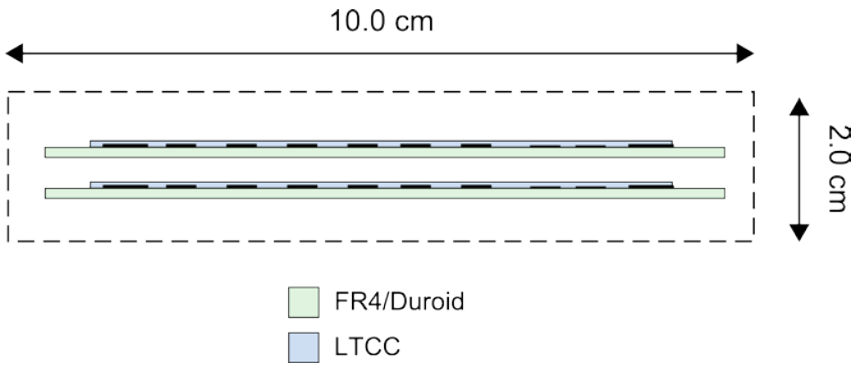


IF Processor Form Factor 2
Horizontal+Vertical (Stacked) Resonators

Top View: 26-channel Panel

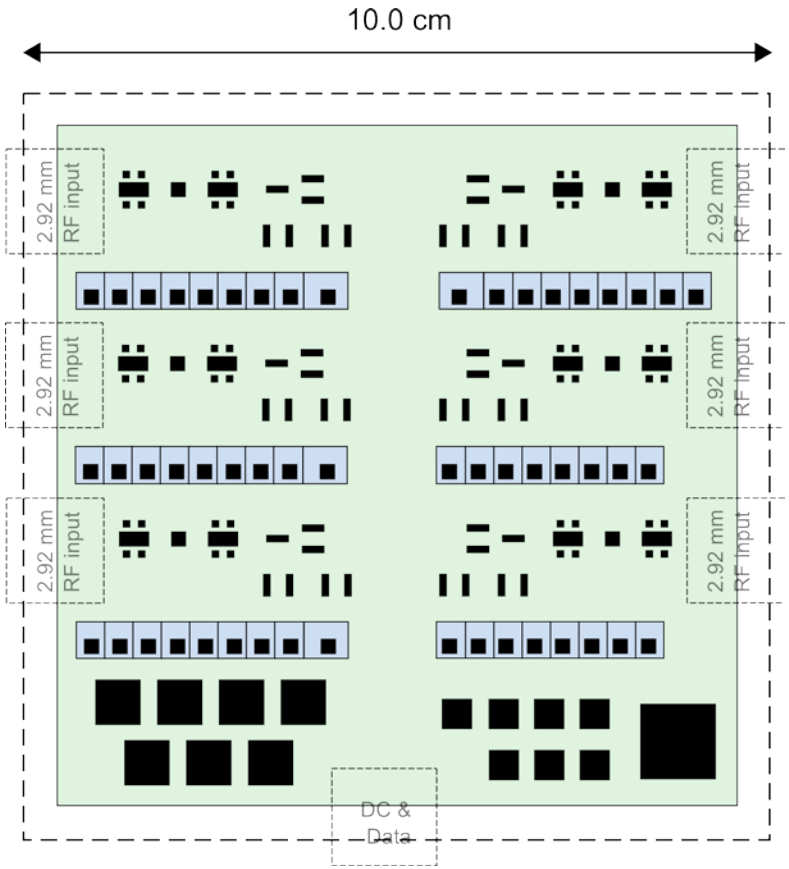


Side View: 52-ch IF Processor

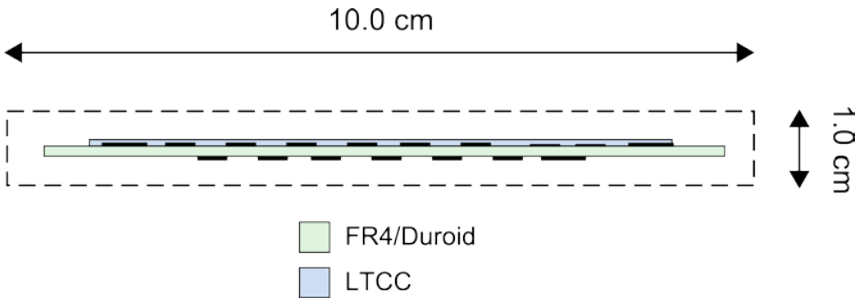


IF Processor Form Factor 3 (Project Goal) Vertical (Stacked) Resonators

Top View: 52-channel Panel



Side View: 52-ch IF Processor

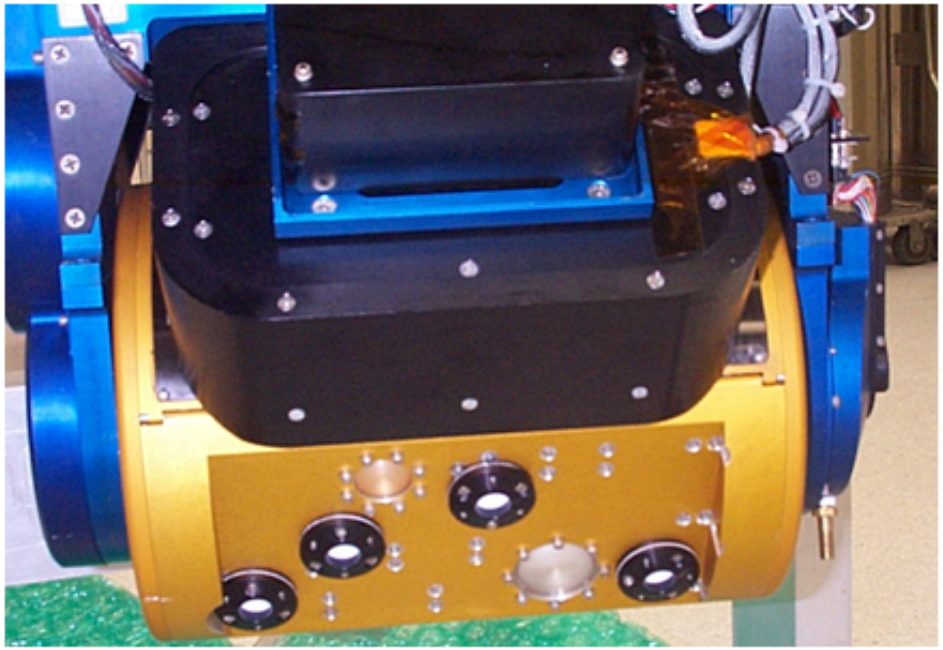


Summary

- **Hyperspectral microwave sensors could change the landscape of atmospheric sounding for both LEO and GEO systems.**
- **An intermediate frequency processor fabricated in LTCC technology is a key innovation enabling ultracompact microwave radiometry in a variety of applications with severe constraints on size, weight, and power.**
- **Fabrication and testing of the hyperspectral microwave receiver subsystem will occur in 2012/2013 with airborne validation in 2014/2015.**

Backup

CoSMIR/CoSSIR Scan Head



The scan head provides calibration and control infrastructure and rotates in azimuth and elevation. CoSSIR is shown in the photo at left.

A compact drum houses the radiometer electronics and rotates relative to the scan head

Flights on the ER-2 have produced many hours of high-quality radiometric data

Frequency Plan

Example: 36 Channels near the 118.75-GHz oxygen line

Channel #	Left edge	Center	Right edge	Bandwidth
1	108.0000	108.5000	109.0000	1.0000
2	113.9135	114.2260	114.5385	0.625
3	114.5375	114.8500	115.1625	0.625
4	115.1615	115.4740	115.7865	0.625
5	115.7855	116.0980	116.4105	0.625
6	116.4095	116.7220	117.0345	0.625
7	117.0335	117.3460	117.6585	0.625
8	117.6575	117.9700	118.2825	0.625
9	118.2815	118.5940	118.9065	0.625

Channels 2-9 above are shifted by 156.25 MHz per band